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7. Cooperation with the industrial hygiene unit of the United States Public Health Service in the studies and investigations of the mental status of workmen as related to output, fitness for the job, protection from health and injury hazards, and permanence of employment.

8. Cooperation with the child hygiene unit of the service in the study and investigation of insanity in children and of the personality of the potentially insane.

9. Cooperation with the Division of Venereal Diseases in studies and investigations of the mental status of prostitutes and of the relation of venereal diseases to mental disorders.

THE TREATMENT OF SEWAGE FROM SINGLE HOUSES AND SMALL COMMUNITIES.[1]

By Earle B. Phelps, Professor of Chemistry, Hygienic Laboratory, United States Public Health Service.

The problem of the treatment and disposal of sewage from isolated homes and small institutions or communities, differs in certain important aspects from the allied problem of city sewage disposal. The composition and physical characteristics of the sewage are, by reason of its nature, somewhat unique. The rate of flow which is always more or less equalized in large systems becomes exceedingly variable in small domestic systems. The necessary available head or fall for the operation of works is generally lacking and pumping is expensive and generally out of the question. Large-scale works require intelligent supervision and more or less constant oversight, which, although not always provided, are at least reasonably possible without involving the project in an undue per capita expense. The small plant, on the other hand, to be entirely successful, must operate with a minimum of such oversight.

Large sums of money have, in the aggregate, been spent in developing sewage treatment methods for the disposal of city sewage, an expenditure which has been amply justified in the resulting economy in design. On the other hand, small works have been designed upon the basis of the general principles, developed by these studies, upon sewages of different types, so that it has been necessary to allow wide margins of safety and to recognize many serious shortcomings, or even failures, in the result. It has seemed important, therefore, to investigate the matter of small disposal installations with the same degree of thoroughness and scientific control that has hitherto been employed in the investigation of city sewage.

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[1] The investigations which are briefly described in this preliminary paper were carried out, under the writer's supervision, by Sanitary Engineer Leslie C. Frank and Assistant Sanitary Engineer C. P. Rhynus during the years 1914-1917. Messrs. Frank and Rhynus have prepared an extensive report embodying the complete results of the investigation, publication of which it has been necessary to delay on account of the war. The present preliminary paper contains a brief outline of the investigation, and is submitted at this time in order that the important conclusions may be made available pending the publication of the complete report.

The experiments were made at two stations, one located at Chevy Chase, Md., and the other on the grounds of the Hygienic Laboratory, Washington. The Chevy Chase plant was located upon an existing private sewer with which some 25 houses were connected. The water supply of the community was from individual driven wells, but most of the houses were equipped with hand or power-driven pumps and a complete running water and modern plumbing system. The situation was, therefore, somewhat typical of situations commonly existing in small towns and frequently in rural districts.

At the Hygienic Laboratory plant sewage was obtained from the nurses' home of the Naval Hospital, which, by reason of an abundant available supply of city water, was somewhat more representative of institutional and small community conditions. The aim has been to confine the studies to a set of conditions commonly met with and to obtain a somewhat general solution as independent as possible of local variables. To this end it will be noted that the devices recommended are capable of exact duplication in any part of the country. This can not be said of processes that utilize the natural soil or artificial beds of stone. To this same end, also, the sewage load has been worked out on a per capita basis and special attention has been given to the variation in permissible loading that accompanies variation in per capita water consumption. The most conspicuous residual variable is that of climatic conditions, and the results must be interpreted with proper regard for that particular factor. With this single exception and with proper appreciation of an allowance for the limitations of the experimental method, it may properly be anticipated that the recommendations that have resulted from this study may be adopted for similar situations elsewhere with every assurance that they are quite applicable to the general situation which they are designed to cover.

The character of the sewages experimented with is shown in Table I, in which the average analyses of the sewages of five small Massachusetts communities have been incorporated for comparison. These latter have been compiled from Metcalf and Eddy.[1]

TABLE I.—*Analyses of crude sewage—General average values.*

From—	Gallons per capita.	Parts per million.				Grams per capita per day.			
		Nitrogen.		Total solids.	Oxygen demand.[1]	Nitrogen.		Total solids.	Oxygen demand.[2]
		Ammoniacal.	Organic.			Ammoniacal.	Organic.		
Hygienic laboratory plant	100	7.9	20.4	981	121	3.0	7.7	372	46
Chevy Chase plant	21	48.0	65.0	1,360	263	3.8	5.2	108	21
Small Massachusetts communities	80	27.2	18.0	603	....	7.9	5.5	183	....

[1] 24-hour, 20°, biochemical oxygen demand.

[2] American Sewage Practice, Vol. II, p. 182.

Public Health Reports, Vol. 34, No. 7, Feb. 14, 1919.

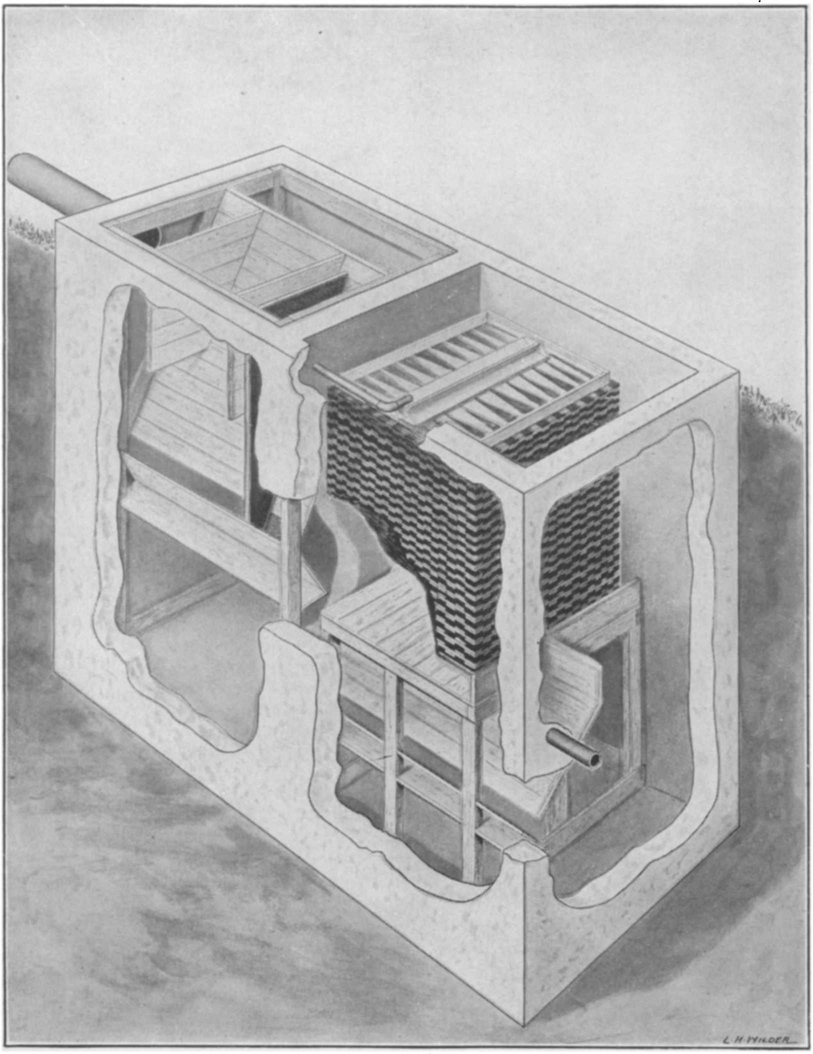

Fig. 1.

Public Health Reports, Vol. 34, No. 7, Feb. 14, 1919.

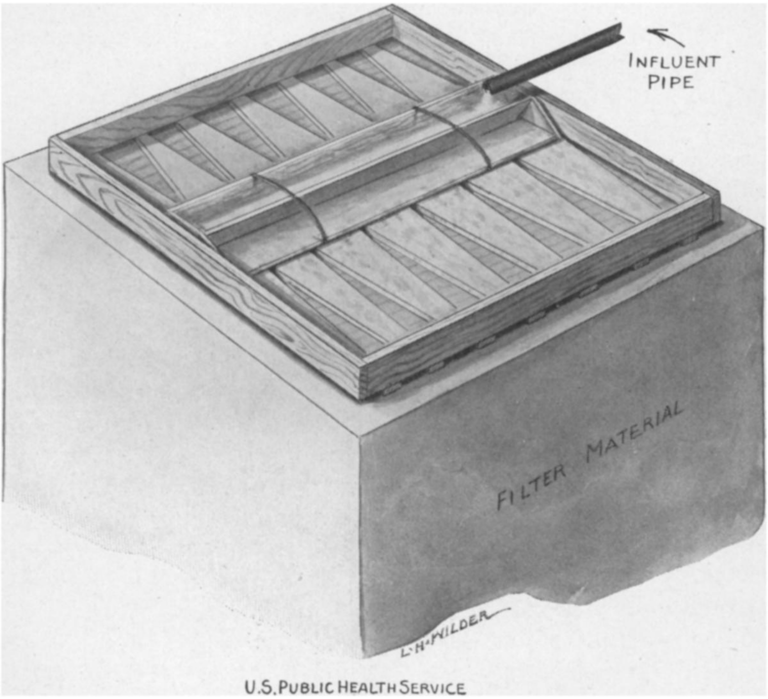

Fig. 2.—Sewage distributor; tipper and tray board, converging boards.

Experiments with preliminary tank treatment were confined to the biolytic tank and the Imhoff tank. The latter has been found particularly well adapted to the special existing requirements. An average removal of 91 per cent of the solids capable of settling was obtained with the Chevy Chase sewage, while with the weaker sewage at the Hygienic Laboratory the corresponding value was 97 per cent. The period of detention was naturally exceedingly variable, but averaged between four and six hours. The sludge accumulation amounted to 2 cubic feet and 3 cubic feet per capita per annum, respectively. Upon the basis of the design which has been worked out sludge removal from these tanks will be required not oftener than twice each year, and possibly not oftener than once each year. The sludge was well digested and inoffensive. It has valuable properties as a fertilizer and with proper restrictions may be so utilized.

Experiments were made with sand filters in order to determine the most advantageous methods of construction and operation under the special conditions imposed. It was found that with moderately coarse sand having an effective size of 0.35 mm. the area required per capita varies with the dilution of the sewage. For the Chevy Chase sewage, with a per capita flow of 20 gallons per day, about 30 square feet of superficial sand area per capita are required. For the Hygienic Laboratory sewage, at 100 gallons per capita per day, a corresponding area of 45 square feet is necessary. Sand layers of 24 inches in depth were found entirely satisfactory. Filter beds should be covered to prevent the growth of vegetation during the summer, and in the colder climates to prevent freezing during the winter. Inspection is required about once a month and raking of the surface about four times each year. A dosing chamber provided with an automatic siphon is an essential adjunct. The chamber should be so dimensioned as to provide a minimum depth of dose of 1 inch over the entire area.

Experiments with trickling filters comprised studies of distributors and studies of filter material. In view of the important results that have been obtained with one particular type of mechanism it will not be necessary to describe these experiments in detail. It has been found that the lath filter developed and described by Nasmith,[1] in combination with a tipping distributer such as has been frequently used in experimental work, possesses advantages over all other types of sewage treatment which merit a complete description of this device. The filter proper, which is shown in figure 1, is built up of layers of ordinary laths, the laths of adjacent layers lying at right angles to one another and those of each layer being parallel and spaced with clear openings of 3 inches. Closer spacing, down to $\frac{3}{4}$ inch, yielded less satisfactory results. The laths of each layer are also so spaced that they come over the center of the open space in the second layer below. A filter depth of 6 feet yields an effluent of high degree of oxidation, and one of $3\frac{1}{2}$ feet yields an effluent sufficiently oxidized to satisfy the requirements of most situations. A total filter volume of 8 cubic feet per capita is required.

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[1] Journal Royal Sanitary Institute XXXVII, 1916.

The details of the distributor which has been most satisfactory are shown in figure 3, while its method of operation is best shown in figure 1. As each compartment becomes nearly full, the device is overbalanced and tips, rocking upon the supporting knife edges. The sewage passes to the tray, the force of the impact being sufficient to cause it to flow as a wave to the ends of the distributor boards. These boards are so tapered that the distribution over the entire area is rendered quite uniform.

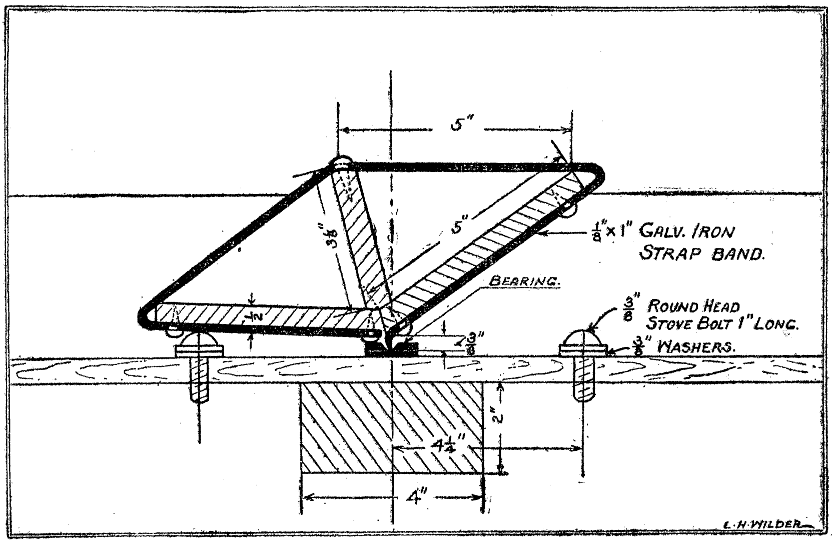
5"
5"
3⅜"
½"
⅛"x1" Galv. Iron Strap Band.
Bearing.
⅜" Round Head Stove Bolt 1" Long.
⅜" Washers.
⅜"
2"
4¼"
4"
L.H. Wilder

Fig. 3.

The performance of this filter is much superior to that of a good trickling filter of stone, and in 6-foot depths, with subsequent sedimentation, is approximately equal to that of a well-operated sand filter 2 feet in depth. This satisfactory result is attributed in part to the well-nigh perfect distribution of sewage over the surface, and in part to the construction of the filter itself, providing, as it does, a large area of horizontal surface over which the sewage passes slowly in exceedingly thin films. That this latter advantage is a real one is indicated by the comparison of results of lath and stone trickling filters operated under identical conditions as to depth and manner of distribution. This is shown in Table II.

TABLE II.—*Average performance of lath and stone filters.*

	Lath.	Stone.
Rate (m. g. a. d.)	2.90	3.12
Relative stability of effluent (per cent)	93	67
Reduction of biochemical oxygen demand (per cent)	89	81
Reduction of organic nitrogen (per cent)	55	29
Nitrogen oxidized (p. p. m.)	4.7	4.0

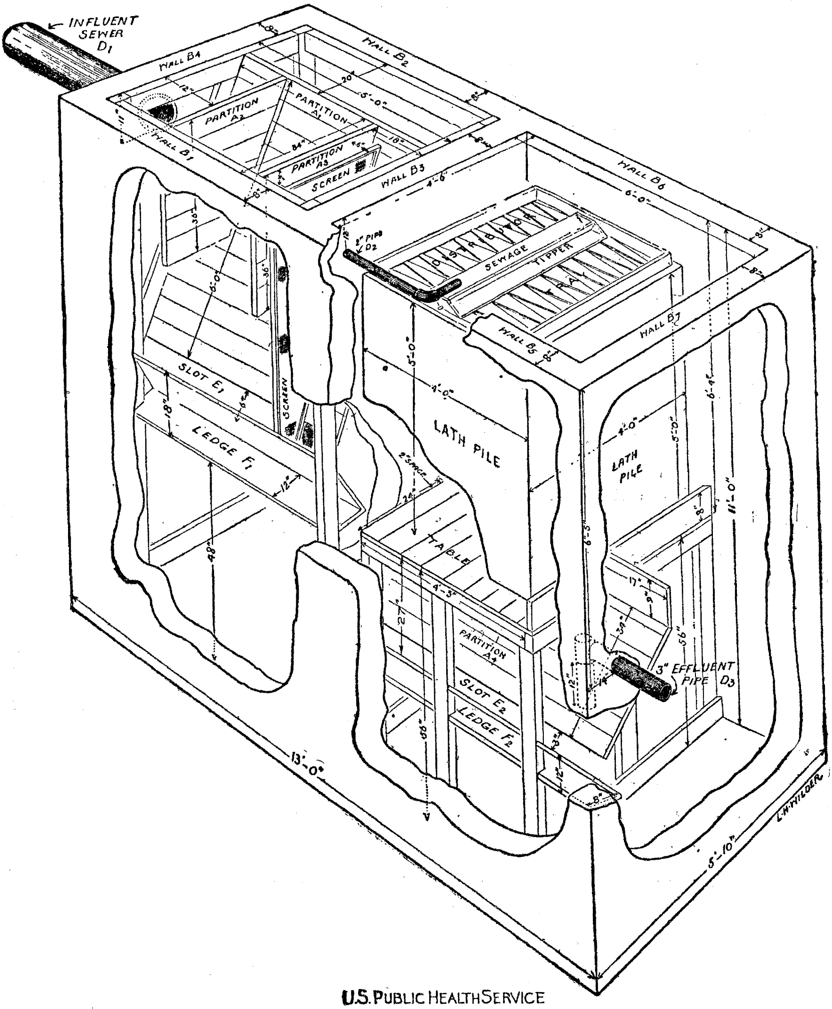

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FIG. 4.—Imhoff tank and lath filter plant for 10 people.

The device fulfills in the most practical way the requirements of satisfactory operation with minimum oversight. There is apparently no tendency toward clogging or deterioration in the filter itself. The rocking distributor might be thought to add a considerable element of uncertainty, but, with the contact of moving parts being confined to the two knife edges, which, by their continuous movement, are necessarily kept clean, no difficulty whatever has been experienced on this score. In fact, since the completion of the experiments the plant at the laboratory station has been running for over a year with inspection not more frequent than once in three months, and only on one occasion was there any necessity for attention. At that time the rocker had entirely left its seat, and deliberate interference by boys of the neighborhood was clearly indicated.

Several complete designs involving preliminary and final Imhoff tanks together with trickling filter have been worked out for populations of from 6 to 120 people. Figure 1 gives the general lay-out which is considered most satisfactory and figure 4 gives the actual dimensions of this plant for a population of 10 people. For smaller populations some reduction in the size of the preliminary Imhoff tank is permissible, but the filter itself could hardly, with advantage, be reduced in size. The general course of the sewage through the plant is plainly indicated. Entering from the main sewer it passes first into a grease trap, thence under the partition A–2, through the main sedimentation chamber, under partition A–3, through the wire screen to the 2-inch outlet pipe which discharges directly into the sewage tipper. It is then distributed over the surface of the filter and flows through the filter to the tight table below, which fits the concrete structure snugly at all points except for the 2 by 24 inch space shown. Through this space it reaches the lower Imhoff tank similar in all respects to the preliminary tank except for the absence of partition baffles. Passing through this tank, it discharges at the effluent pipe D–3. During the passage of the sewage through the Imhoff tanks, the suspended solids are deposited upon the sloping partition from which they slide by gravity, ultimately reaching the lower or sludge compartment. Here digestion takes place, the gases and scum rising along the underside of the sloping partition to the vent chamber. Through this chamber the sludge is removed at necessary intervals. It is estimated that the cost of materials and labor for a plant of this capacity will be about $250. The degree of purification effected is sufficient for all purposes except where the discharge is directly into a water supply. In such a case chemical disinfection of the effluent is recommended in addition. In the northern sections of the country it will be desirable to provide heavy plank covers for protection against winter weather. The plant will operate without nuisance, and, with a monthly inspection and semiannual or annual removal of sludge from the tanks, will operate continuously without further attention.